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GASDYNAMIC FUNCTION CHARACTERIZING THE FLUX MOMENTUM EXPRESSED IN TERMS OF VARIOUS PARAMETERS APPROPRIATE TO DISSOCIATING NITROGEN TETROXIDE

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Various expressions for an important gasdynamic function characterizing the gas-flux momentum are obtained.

The present investigation, in which various expressions for the flux momentum are derived, is a continuation of [1], where a series of gasdynamic functions was considered.

The function expressing the momentum of a flux is written in the form

$$J = Gw + pF. \tag{1}$$

But since G = ρwF, it follows that

$$J = G\left(w + \frac{p}{\rho w}\right). \tag{2}$$

In [1], the following expressions were obtained:

$$a^2_{\mathrm{cr}} = \xi^2_{\mathrm{cr}} 2\,\frac{k}{k+1}\,\frac{R}{\mu_{N_2O_4}}\,T_0 \tag{3}$$

and

$$\frac{T_0}{T} = \left\{1 + \frac{1}{\eta}\,\frac{k_T - 1}{k_T}\,[(Z_{\mathrm{ef}})_{p,T} - (Z_{\mathrm{ef}})_{p_0,T}]\right\}\left(1 - \frac{1}{\eta}\,\frac{k_T - 1}{k_T}\,\frac{k}{k+1}\,\xi^2_{\mathrm{cr}}\lambda^2\right)^{-1}, \tag{4}$$

where

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$$\xi^2_{\mathrm{cr}} = \frac{k+1}{2} y^2_{\mathrm{cr}} \left[1 + \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} \left\{\frac{k}{2} y^2_{\mathrm{cr}} - [(Z_{\mathrm{ef}})_{p_0, T_{\mathrm{cr}}} - (Z_{\mathrm{ef}})_{p_{\mathrm{cr}}, T_{\mathrm{cr}}}]\right\}\right]; \tag{5}$$

$$\frac{k_T - 1}{k_T} = \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{p_{\mathrm{cr}}}}; \tag{6}$$

$$y_{\mathrm{cr}} = \left[k \sqrt{\eta_{\mathrm{cr}} - \frac{R}{\mu_{N_2O_4} (C_{p\mathrm{ef}})_{\mathrm{cr}}} \omega^2_{\mathrm{cr}}}\right]^{-1} (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p_{\mathrm{cr}}, T_{\mathrm{cr}}} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p_{\mathrm{cr}}, T_{\mathrm{cr}}}. \tag{7}$$

Since $p = \rho Z_{ef}(R/\mu_{N_2O_4})/T_0$, taking account of Eqs. (3) and (4) gives

$$\frac{p}{\rho} = (Z_{\mathrm{ef}})_{p,T} \frac{R}{\mu_{N_2O_4}} T_0 \left\{1 + \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} [(Z_{\mathrm{ef}})_{p,T} - (Z_{\mathrm{ef}})_{p_0, T}]\right\} \left(1 - \frac{k}{k+1} \xi^2_{\mathrm{cr}} \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} \lambda^2\right)^{-1}. \tag{8}$$

Substituting Eq. (8) into Eq. (2), and taking into account that $w^2 = a^2_{\mathrm{cr}}\lambda^2$, it is found that

$$J = G \left[\lambda a_{\mathrm{cr}} + \frac{k+1}{2k} \frac{(Z_{\mathrm{ef}})_{p,T}\, a_{\mathrm{cr}}}{\lambda \xi^2_{\mathrm{cr}}} \left(1 - \frac{1}{\bar{\eta}} \frac{k}{k+1} \frac{k_T - 1}{k_T} \xi^2_{\mathrm{cr}} \lambda^2\right) \left\{1 + \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} [(Z_{\mathrm{ef}})_{p,T} - (Z_{\mathrm{ef}})_{p_0, T}]\right\}^{-1}\right]. \tag{9}$$

As is known [2]

$$Z_{\mathrm{ef}} = (1 + \alpha_{10} + \alpha_{10}\alpha_{20}) \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right). \tag{10}$$

Then

$$\begin{aligned} J = G\Bigg[\lambda a_{\mathrm{cr}} &+ \frac{k+1}{2k} \frac{a_{\mathrm{cr}}}{\lambda \xi_{\mathrm{ef}}} (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p,T} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} \\ &\times \left(1 - \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{p\mathrm{ef}}} \frac{k}{k+1} \xi^2_{\mathrm{cr}} \lambda^2\right) \Bigg\{1 + \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{p\mathrm{ef}}} \\ &\times \left[(1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p,T} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} - (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p_0, T} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0, T}\right]\Bigg\}^{-1}\Bigg]. \end{aligned} \tag{11}$$

For an ideal gas ($k_T = k$; $Z_{ef} = 1$; $\xi_{cr} = 1$; $\bar{\eta} = 1$), Eq. (11) takes the form [3]

$$J_{\mathrm{id}} = \frac{k+1}{2k} G a_{\mathrm{id}} \left(\lambda_{\mathrm{id}} + \frac{1}{\lambda_{\mathrm{cr}}}\right). \tag{12}$$

The first derivation of Eq. (12) for the momentum of a gas flux, which offers the possibility of solving various gasdynamic problems for an ideal gas, was in [4].

The momentum of a flux may be related to another important function: the reduced pressure (dimensionless pressure parameter), which forms the basis of the calculation system proposed and used in [5, 6] in theoretical and experimental investigations concerning the drag coefficient.

The reduced pressure (π_{re}) is the ratio of the gas pressure p to the product of the critical velocity of the ideal gas as a process constant and the specific mass flux of gas [5] $\rho w = G/F$. Thus

$$\pi_{\mathrm{re}} = \frac{p}{\rho w a_{\mathrm{cr}}} \tag{13}$$

or rewriting Eq. (13) to take into account that $w^2 = a^2_{cr}\lambda^2$

$$\pi_{\mathrm{re}} = \frac{p}{\rho \lambda a^2_{\mathrm{cr}}}. \tag{14}$$

Using Eqs. (3) and (4) and the equation of state in the form

$$p = \rho (Z_{\mathrm{ef}})_{p,T} \frac{R}{\mu_{N_2O_4}} T,$$

the following expression is obtained for a real gas:

$$\pi_{\mathrm{re}} = \frac{k+1}{2k} \frac{(Z)_{p,T}}{\xi^2_{\mathrm{cr}}} \frac{1}{\lambda} \left(1 - \frac{1}{\bar{\eta}} \frac{k}{k+1} \xi^2_{\mathrm{cr}} \frac{k_T - 1}{k_T} \lambda^2\right) \left\{1 - \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} [(Z)_{p,T} - (Z)_{p_0, T}]\right\}^{-1}, \tag{15}$$

where Z is the compressibility coefficient for a real gas, as is known.

For dissociating nitrogen tetroxide, the reduced pressure may be written in the form*

$$\pi_{re} = \frac{k+1}{2k}\frac{1}{\xi_{cr}^2}\frac{1}{\lambda}(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}$$

$$\left(1-\frac{1}{\bar\eta}\xi_{cr}^2\frac{k}{k+1}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\lambda^2\right)\left\{1+\frac{1}{\bar\eta}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\times\right.$$

$$\left.\times\left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}-(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{-1}. \quad (16)$$

Equation (2) is rewritten in the form

$$J = G\left(\lambda a_{cr}+\frac{p}{\rho\lambda a_{cr}}\right)$$

or

$$J = Ga_{cr}\left(\lambda+\frac{p}{\rho\lambda a_{cr}^2}\right). \quad (17)$$

In [1]

$$a_{cr}^2 = y_{cr}^2 k\frac{R}{\mu_{N_2O_4}}T_{cr}, \quad (18)$$

and also

$$\frac{\rho_0}{\rho} = \frac{(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}}{(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T_0}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T_0}}\times$$

$$\times\left\{1+\frac{1}{\bar\eta}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}-\right.\right.$$

$$\left.\left.-(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{\frac{1}{k_T-1}}\left(1-\frac{1}{\bar\eta}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\frac{k}{k+1}\xi_{cr}^2\lambda^2\right)^{-\frac{1}{k_T-1}}. \quad (19)$$

Simultaneous solution of Eqs. (14) and (17)-(19) gives, after appropriate manipulations,

$$I = Fp_0\left(1-\frac{1}{\bar\eta}\xi_{cr}^2\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\frac{k}{k+1}\lambda^2\right)^{\frac{1}{k_T-1}}\times$$

$$\times\left\{1+\frac{1}{\bar\eta}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}-\right.\right.$$

$$\left.\left.-(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{-\frac{1}{k_T-1}}\times$$

$$\times\left[\lambda^2\xi_{cr}^2\frac{2k}{k+1}(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}^{-1}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)^{-1}+\right.$$

$$+\left(1-\frac{1}{\bar\eta}\xi_{cr}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\frac{k}{k+1}\lambda^2\right)\left\{1+\frac{1}{\bar\eta}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\times\right.$$

$$\times\left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}-\right.$$

$$\left.\left.\left.-(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}\right]\right\}^{-1}\right]. \quad (20)$$

*The subscript re is introduced to distinguish π_{re} from π, which appears in Eq. (16) and denotes the ratio of the gas pressure to the critical pressure of the material p/p_{cr}.

The concept of a reduced temperature introduced in [6] may be used as another gasdynamic function*

$$\tau_{re} = T/T_{cr}. \tag{21}$$

In [1] it was found that

$$\xi_{cr}^2 = \frac{k+1}{2} y_{cr}^2 \frac{T_{cr}}{T_0}. \tag{22}$$

Then

$$\tau_{re} = \frac{T}{T_0} \frac{1}{\xi_{cr}^2} \frac{k+1}{2} y_{cr}^2. \tag{23}$$

Substitution of T/T_0 from Eq. (4) gives

$$\tau_{re} = \frac{k+1}{2}\left(\frac{y_{cr}}{\xi_{cr}}\right)^2 \left\{1 + \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} [(Z_{ef})_{p,T} - (Z_{ef})_{p_0,T}]\right\}^{-1} \left(1 - \frac{1}{\bar{\eta}} \frac{k}{k+1} \frac{k_T - 1}{k_T} \xi_{cr}^2 \lambda^2\right). \tag{24}$$

Equation (24) is applicable to any real gas if Z_{ef} is understood to denote the compressibility coefficient. For dissociating nitrogen tetroxide, Eq. (24) takes the form

$$\tau_{re} = \frac{k+1}{2} \frac{y_{cr}^2}{\xi_{cr}^2} \left\{1 + \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{p\,ef}} \left[(1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p,T} \times \right.\right.$$
$$\times \left(1 + \sum_{i=1}^{3}\sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} - (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p_0,T} \times$$
$$\left.\left. \times \left(1 + \sum_{i=1}^{3}\sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{-1} \left(1 - \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \frac{k}{k+1} \xi_{cr}^2 \lambda^2\right). \tag{25}$$

On the basis of Eqs. (13) and (22), the relation between π_{re} and τ_{re} is expressed in the form

$$\frac{\pi_{re}\lambda}{\tau_{re}} = \frac{1}{k} \frac{(Z_{ef})_{p,T}}{y_{cr}^2} \tag{26}$$

or

$$\frac{\pi_{re}\lambda}{\tau_{re}} = \frac{1}{k y_{cr}^2} (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p,T} \left(1 + \sum_{i=1}^{3}\sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right). \tag{27}$$

Taking account of Eq. (14), Eq. (17) is written in the form [3]

$$J = G a_{cr} (\lambda + \pi_{re}). \tag{28}$$

Determining π_{cr} from Eq. (26) and substituting the result into Eq. (28), it is found that

$$J = G a_{cr} \lambda \left[1 + \frac{1}{k} \frac{(Z_{ef})_{p,T}}{y_{cr}^2} \frac{\tau_{re}}{\lambda^2}\right] \tag{29}$$

or

$$J = G a_{cr} \lambda \left[1 + \frac{1}{k y_{cr}^2} \frac{\tau_{re}}{\lambda^2} (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p,T} \left(1 + \sum_{i=1}^{3}\sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}\right]. \tag{30}$$

Simultaneous solution of Eqs. (18), (19), and (30), taking into account that $w^2 = a_{cr}^2\lambda^2$ and $\rho w = G/F$, gives an expression for the flux momentum in terms of the stagnation pressure and the reduced temperature, which takes the following form after appropriate manipulations:

$$J = \xi_{cr}^2 (1 + \alpha_{10} + \alpha_{10}\alpha_{20})_{p,T}^{-1} \left(1 + \sum_{i=1}^{3}\sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}^{-1} \times \tag{31}$$

*The subscript re is introduced to distinguish τ_{re} from τ, which appears in a series of dependences and denotes the ratio of the gas temperature to the critical temperature of the material.

$$\times \frac{2k}{k+1} F p_0 \left[\lambda^2 + \tau_{re} \frac{1}{k y_{cr}^2} (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T} \times \right.$$

$$\left. \times \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}\right] \left(1 - \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \frac{k}{k+1} \xi_{cr}^2 \lambda^2\right)^{\frac{1}{k_T - 1}} \times$$

$$\times \left\{1 + \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} - \right.\right.$$

$$\left.\left. - (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{-\frac{1}{k_T - 1}}. \tag{31}$$

The adiabatic equation is used

$$\frac{T_0}{T} = \left(\frac{p_0}{p}\right)^{\frac{K_T - 1}{K_T}}. \tag{32}$$

To express the flux momentum in terms of the static pressure p, the stagnation pressure in Eq. (31) must be replaced by the corresponding expression including the static pressure. To this end, Eqs. (4), (10), (20), and (32) are solved simultaneously and the result is rearranged to give

$$J = Fp \left(1 - \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \frac{k}{k+1} \xi_{cr}^2 \lambda^2\right)^{-1} \times$$

$$\left\{1 + \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T} \times \right.\right.$$

$$\times \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} - (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T} \times$$

$$\left.\left. \times \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\} \times$$

$$\times \left\| \left[\lambda^2 \xi_{cr}^2 (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}^{-1} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}^{-1} \times \right.\right.$$

$$\times \frac{2k}{k+1} + \left(1 - \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \frac{k}{k+1} \xi_{cr}^2 \lambda^2\right)$$

$$\times \left\{1 + \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T} \times \right.\right.$$

$$\times \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} - (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T} \times$$

$$\left.\left.\left.\left. \times \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{-1}\right]\right\|. \tag{33}$$

The flux momentum expressed in terms of the static pressure and the reduced temperature is found in the following form after simultaneous solution of Eqs. (4), (10), (31), and (32)

$$J = Fp \xi_{cr}^2 (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}^{-1} \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}^{-1} \times$$

$$\times \frac{2k}{k+1} \left[\lambda^2 + \tau_{re} \frac{1}{k y_{cr}^2} (1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T} \times \right.$$

$$\left. \times \left(1 + \sum_{i=1}^{3} \sum_{j=0}^{4} \frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T} \left(1 - \frac{1}{\bar{\eta}} \frac{R}{\mu_{N_2O_4}} \frac{\omega}{C_{pef}} \frac{k}{k+1} \xi_{cr}^2 \lambda^2\right)^{-1}\right] \times$$

$$\times\left\{1+\frac{1}{\bar{\eta}}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\times\right.\right.$$
$$\times\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}-$$
$$\left.\left.-(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}. \tag{34}$$

The function expressing the ratio between the velocity difference and the stagnation pressure takes the form

$$\frac{\rho w^2}{2p_0}=\frac{(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T_0}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T_0}}{(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}}$$
$$\times\ \xi_{cr}^2\frac{k}{k+1}\lambda^2\left(1-\frac{1}{\bar{\eta}}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{pef}}\frac{k}{k+1}\xi_{cr}^2\lambda^2\right)^{\frac{1}{k_T-1}}$$
$$\times\left\{1+\frac{1}{\bar{\eta}}\frac{R}{\mu_{N_2O_4}}\frac{\omega}{C_{p\,ef}}\left[(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p,T}\right.\right.$$
$$\left.\left.-(1+\alpha_{10}+\alpha_{10}\alpha_{20})_{p_0,T}\left(1+\sum_{i=1}^{3}\sum_{j=0}^{4}\frac{a_{ij}\pi^i}{\tau^j}\right)_{p_0,T}\right]\right\}^{-\frac{1}{k_T-1}}. \tag{35}$$

Considering all the expressions obtained for various gasdynamic functions in the case of dissociating nitrogen tetroxide, it may be concluded that the tabular data on gasdynamic functions for an ideal gas cannot be used in finding the gasdynamic function for nitrogen tetroxide from the complicated expressions obtained.

Thus, all the theoretical problems involving a flux of dissociating gas must be based on the method of successive approximation.

As an illustration, consider, for example, the determination of the momentum of a flux of dissociating nitrogen tetroxide from Eq. (34).

It is assumed that the parameters p and T are taken among the specified quantities. The problem of determining the flux momentum J from specified quantities, i.e., the velocity coefficient λ, static pressure p, and cross section F.

From the specified temperature T, the equilibrium constants of the two reaction phases are determined, and then the degrees of dissociation α_{10} and α_{20} are found from the specified p.

The value of C_{pef} is taken from the tables cited in [1]. The coefficients η and ω are found from the corresponding expressions in [2].

To find ξ_{cr} from Eq. (6) and y_{cr} from Eq. (7), it is necessary to know the stagnation pressure (p_0) and the critical parameters (p_{cr} and T_{cr}). For this purpose, the well-known relations for ideal gases may be taken as a first approximation

$$\left(\frac{p_{cr}}{p_0}\right)_{id}=\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}},$$
$$\left(\frac{T_{cr}}{T_0}\right)_{id}=\frac{2}{k+1},$$
$$\left(\frac{T_0}{T}\right)_{id}=\left(1-\frac{k-1}{k+1}\lambda_{id}^2\right)^{-1},$$
$$\left(\frac{p_0}{p}\right)_{id}=\left(1-\frac{k-1}{k+1}\lambda_{id}^2\right)^{-\frac{k}{k-1}}. \tag{36}$$

Taking $\lambda_{id} \approx \lambda$ in the first approximation, and also the value of k for nitrogen tetroxide in the range $k \approx 1.1$-1.2, the stagnation parameters and then the critical parameters of the flux are found in the first approximation. This offers the possibility of finding ξ_{cr} and y_{cr} in the first expression from Eqs. (6) and (7).

In [1], it was found that

$$\frac{p_0}{p} = \left\{1 + \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} [(Z_{ef})_{p,T} - (Z_{ef})_{p_0,T}] \right\}^{\frac{k_T}{k_T - 1}} \left(1 - \frac{1}{\bar{\eta}} \frac{k_T - 1}{k_T} \frac{k}{k + 1} \xi_{cr}^2 \lambda^2 \right)^{-\frac{k_T}{k_T - 1}}. \quad (37)$$

Now turning to Eqs. (4), (6), and (37), T_0 and p_0 are found in the second approximation and, using Eqs. (6) and (7), ξ_{cr} and y_{cr} are determined in the second approximation. If the approximation problem is completely adequate, the reduced temperature τ_{cr} is determined from Eq. (25), and then the flux momentum from Eq. (34).

Iteration is found to be rapid in practice with this procedure of successive approximation.

The expressions obtained for the gas-flux momentum depend on a series of quantities with the same physical meaning as in [1], where a series of gasdynamic functions was derived for a chemically reacting system.

If the thermophysical and chemical properties of the dissociating gases are ignored, Eq. (11) turns into the well-known dependence in Eq. (12) proposed in [4], as shown above. However, Eq. (12) cannot be used for a dissociating gas, of course, since it was obtained on the basis of the ideal-gas state.

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